Novel EUV Resist Materials Design for 15 nm Half Pitch and Below

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FUJIFILM Corporation

Outline

1. Motivation
2. Resist design for 15 nm HP and below
3. Latest FUJIFILM EUV resist
4. Summary

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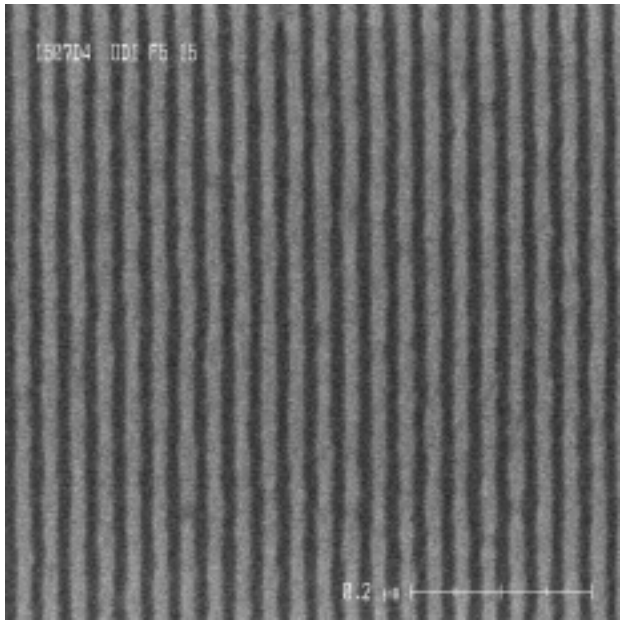
FUJIFILM EUV resist performances

-- FEVS-P1507D4 --

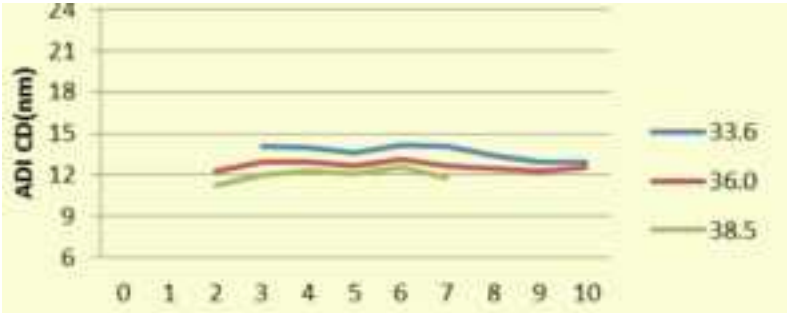
15 nm HP

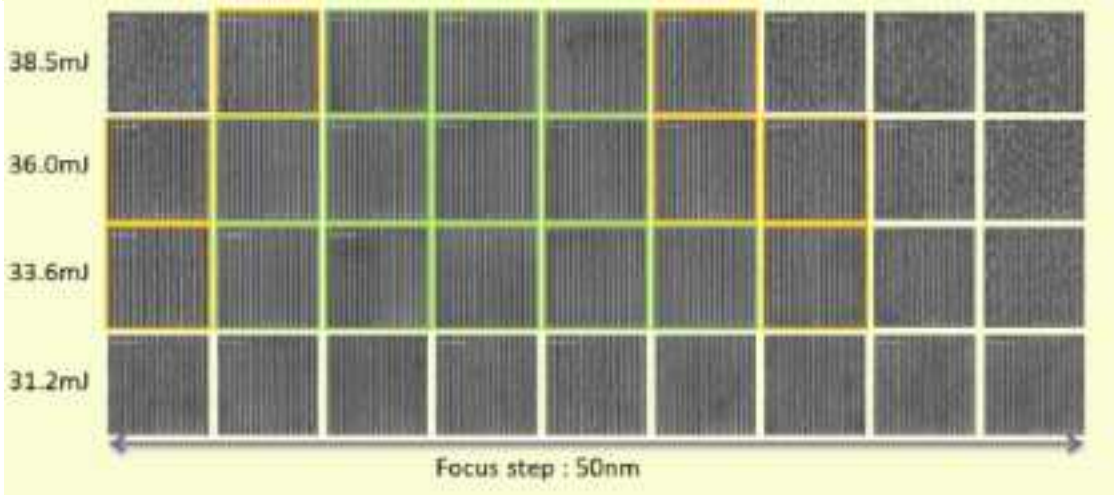
Esize (mJ/cm²)	LWR (nm)	EL (%)	Max DOF (nm)
30.8 ☹	3.0 ☹	23.2 ☺	200 ☺

Courtesy of SEMATECH
EUVL symposium 2012,
LBNL MET with PPSM illumination



Esize =30.8 mJ/cm²
LWR = 3.0 nm

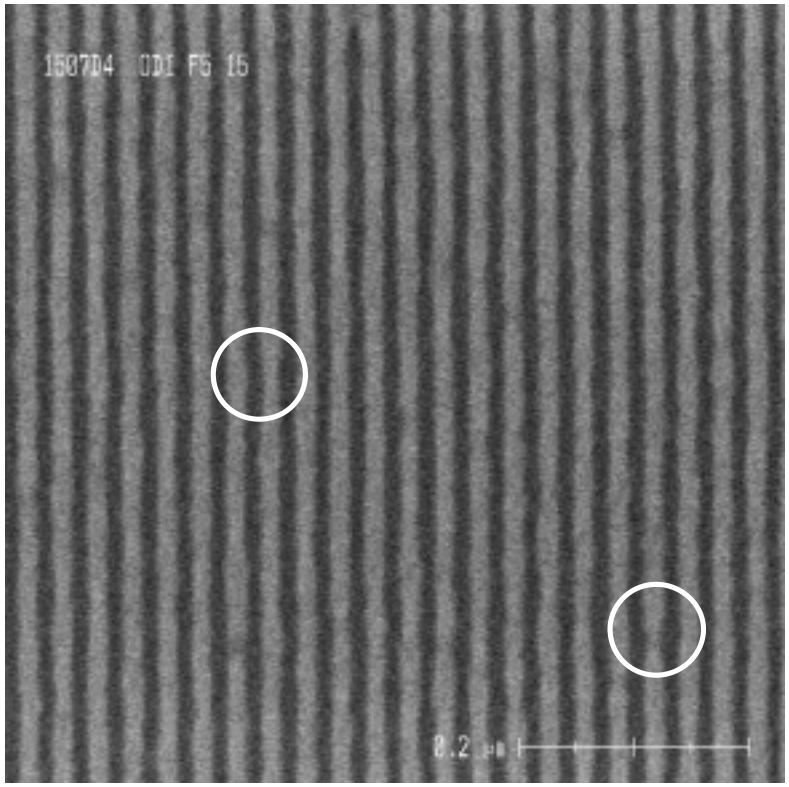




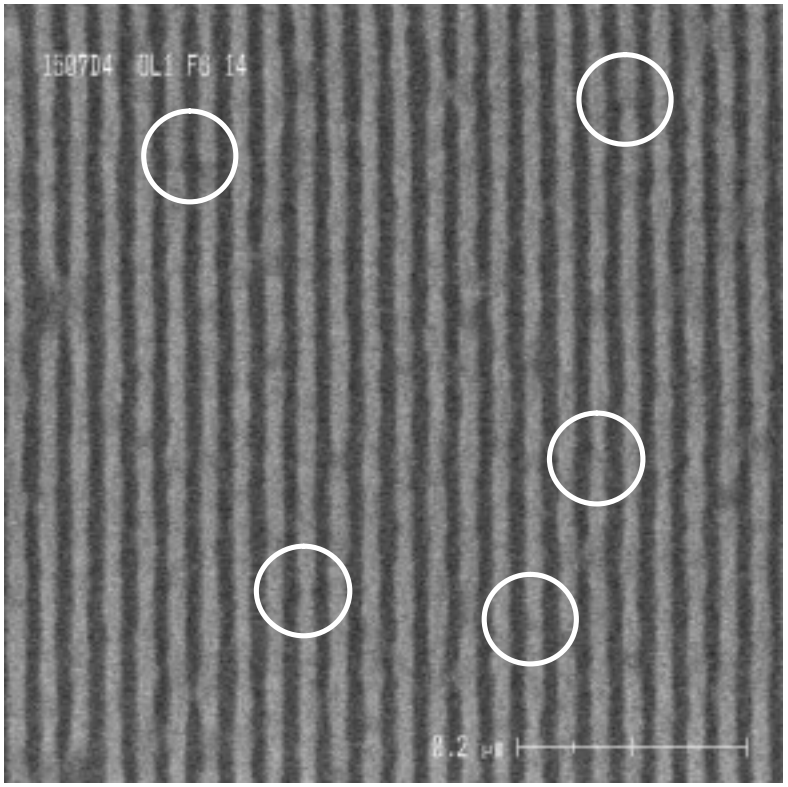
Key issues on 15 nm hp and below

-- FEVS-P1507D4 --

15 nm HP



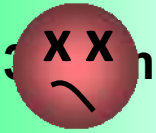
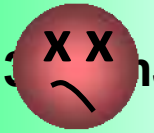
14 nm HP



30.8 mJ/cm^2

Severe pinching degrades pattern quality (LWR)

Status of FUJIFILM EUV resist

Performance	Requirement	Status	Our policy
Resolution	< 16 nm		Hydrophobic resin *SPIE2012* Short diff. acid *SPIE2013*
LWR	< 2.0 nm		Short diff. acid High Tg resin EUV sensitizer } *This work*
Sensitivity	< ~ 20 mJ/cm²		Low Ea resist *SPIE2013*
Process window	200 nm DOF @10%EL		--
Defectivity	< 0.1 cm²	?	EUV additive *SPIE2012*
Outgassing	Cleanable < 3.0nm Non-clean < 0.16%		Non-volatile PAG Topcoat *SPIE2013*

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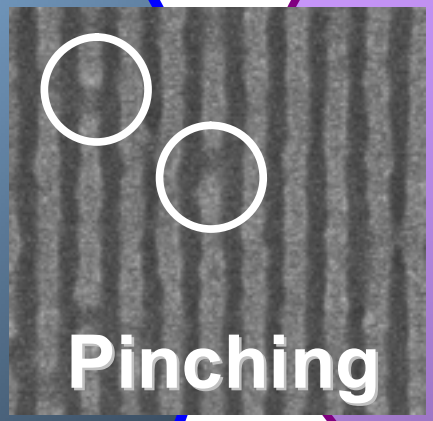
Proposed origins of pinching

Material Factor

1. Chemical Contrast Degradation
   ⇒ acid diffusion
2. Acid noise

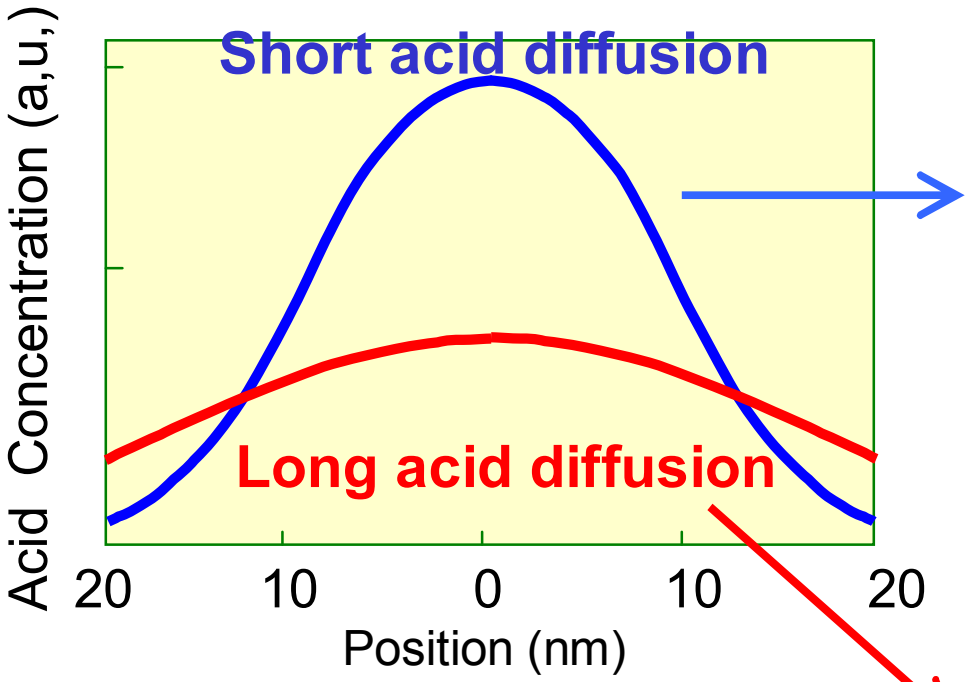


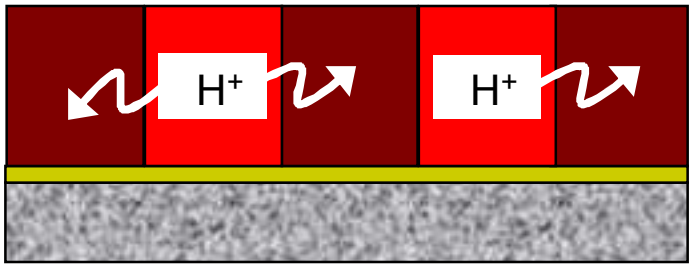
Optical Factor

1. Optical Contrast Degradation
2. Photon Shot Noise
3. Mask Roughnes

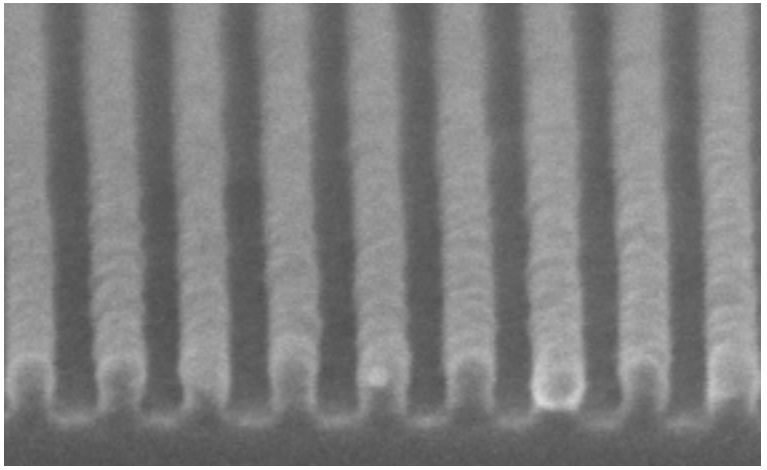
High contrast and low acid noise design are necessary

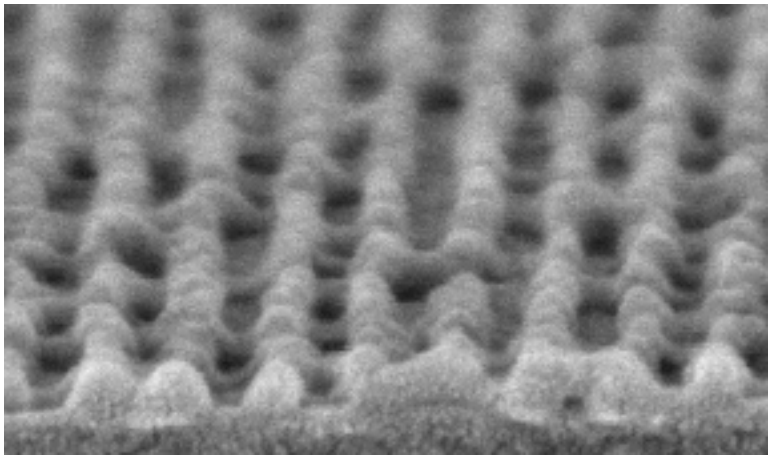
Impact of acid diffusion





hp 20nm EUVL

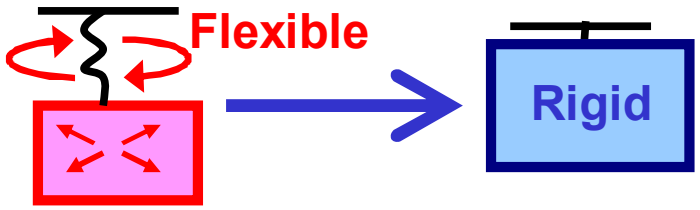


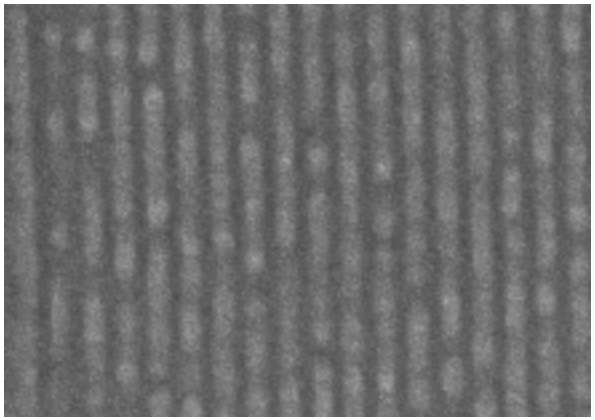
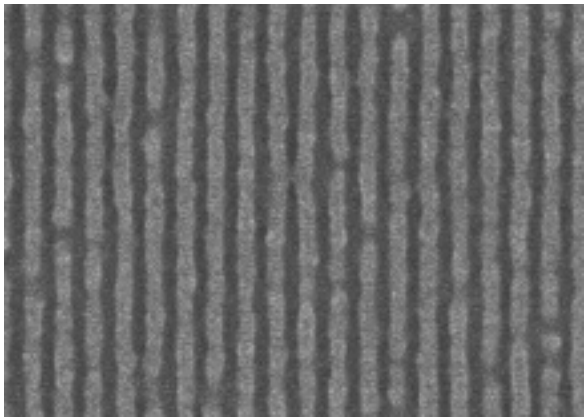
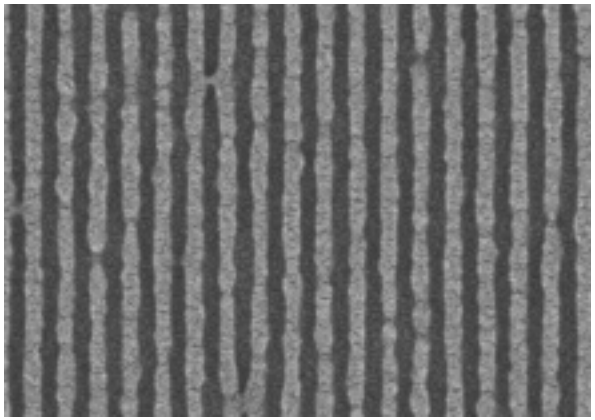


Diffusion is important because EUV is narrow pitch

Acid diffusion suppression

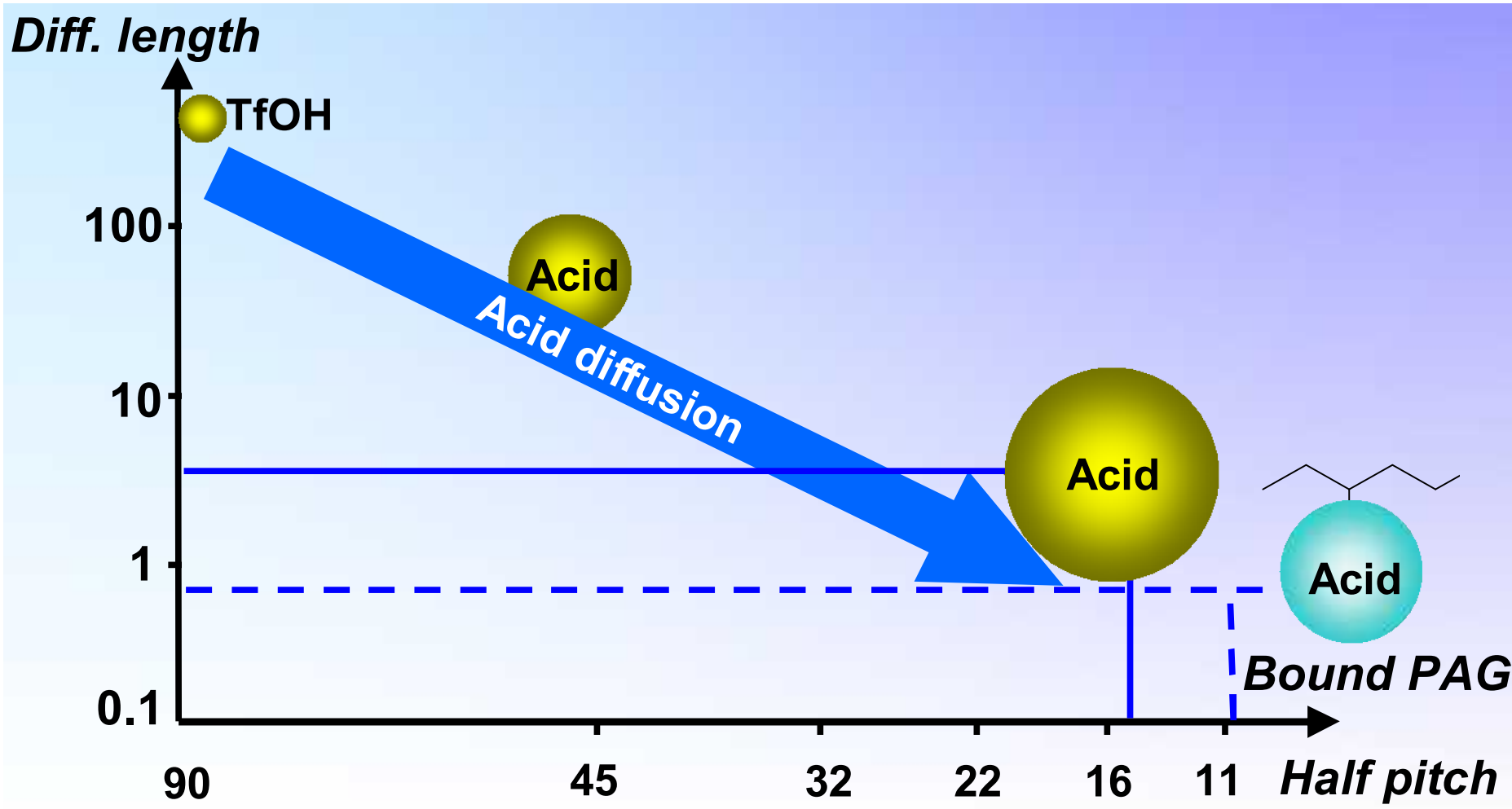
HP 15 nm
LBNL MET data
PPSM illumination (NA 0.3)



Small molecular acid Std. polymer	**Large molecular acid** Std. polymer	**Large molecular acid** **High Tg polymer**
		
Esize = 30 mJ/cm^2 LWR = -- nm severe top loss	Esize = 36 mJ/cm^2 LWR = 4.7 nm nZ = 1.0	Esize = 45 mJ/cm^2 LWR = 3.8 nm nZ = 0.8

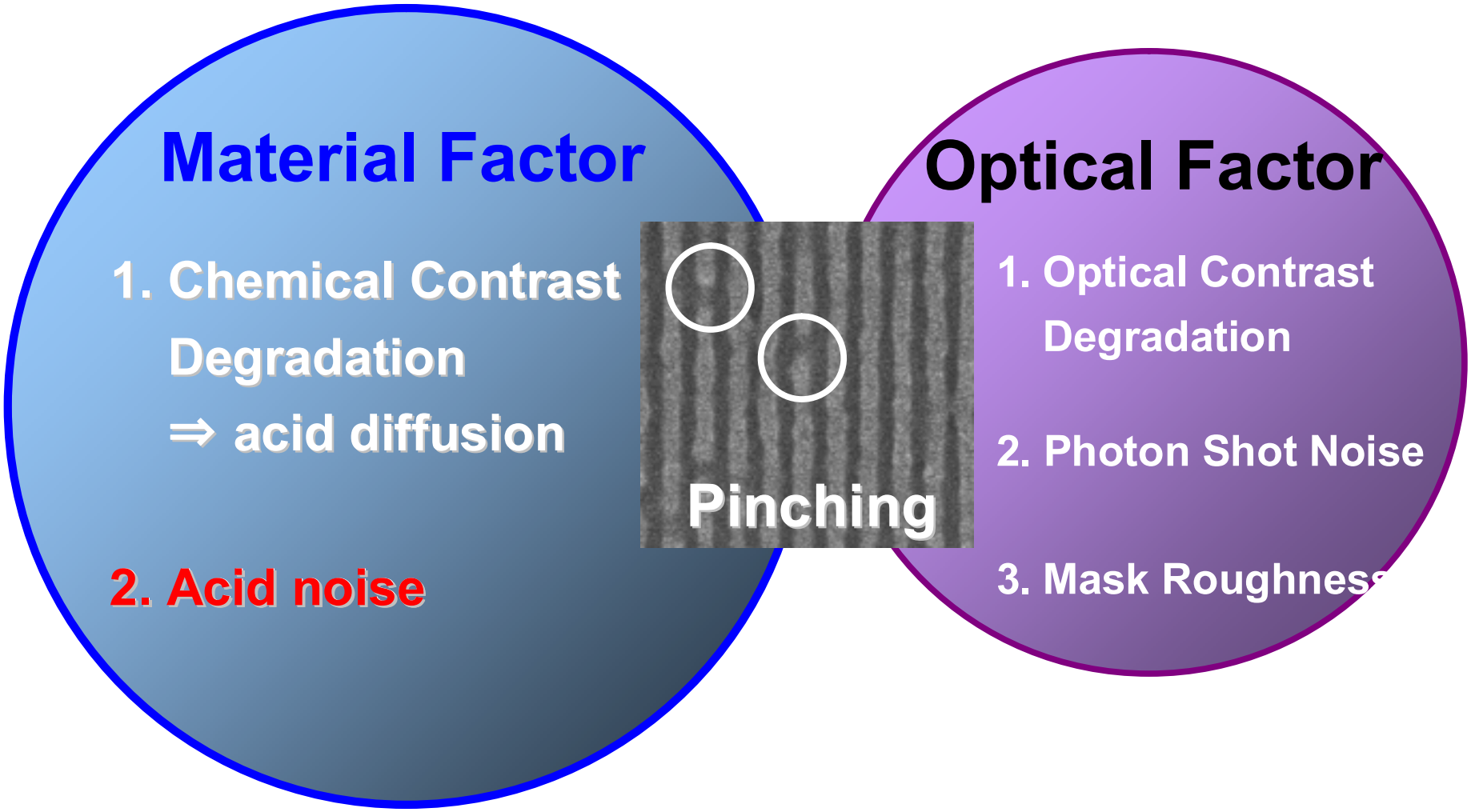
Large acid and high Tg resin gave best LWR / Z factor

Acid design for each technology node



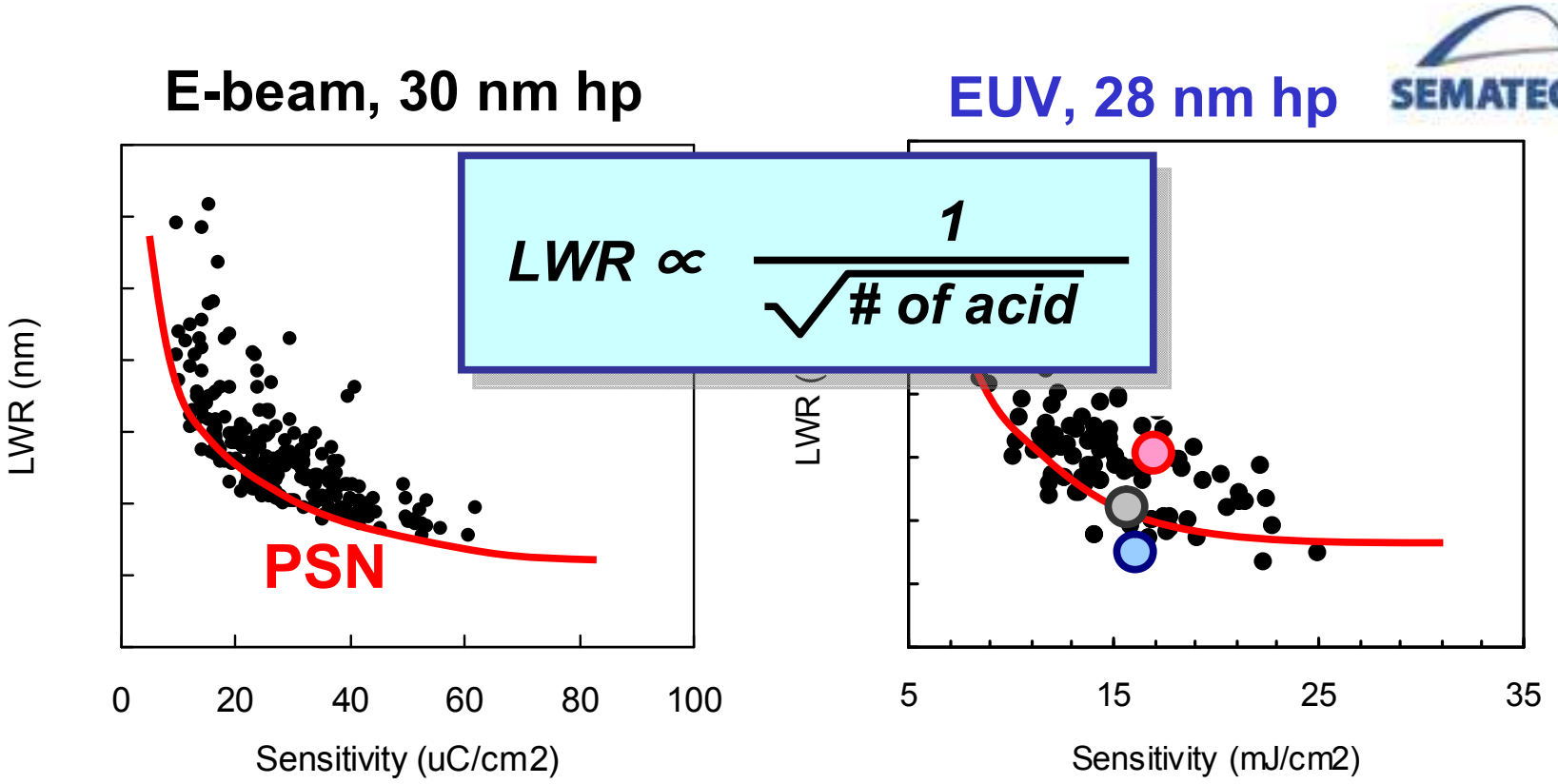
Molecular PAG should be still effective for 15nm hp

Proposed origins of pinching



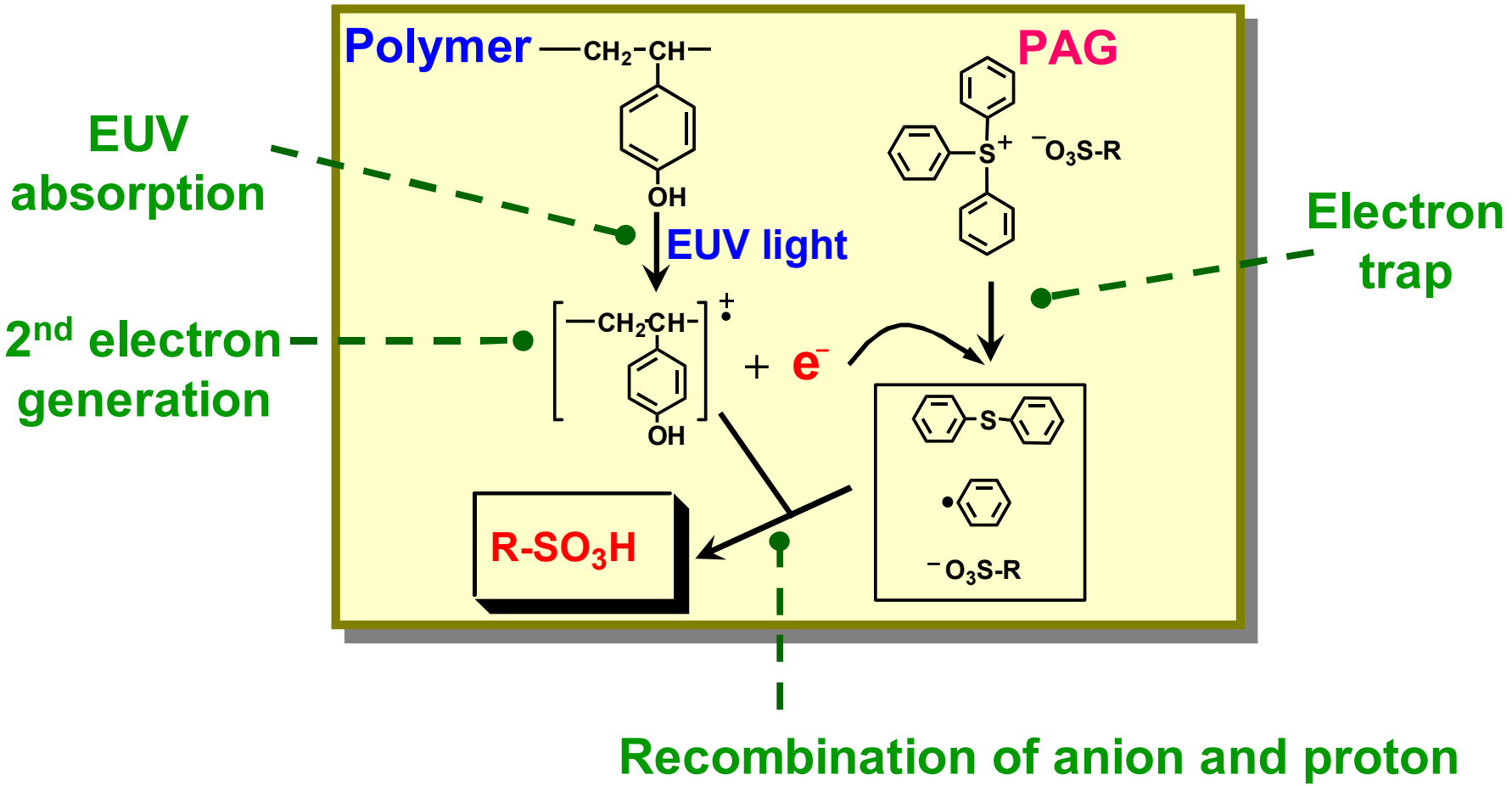
High contrast and low acid noise design are necessary

Noise determines LWR / pinching



Acid noise also determines LWR,
so noise reduction by increasing acid is important

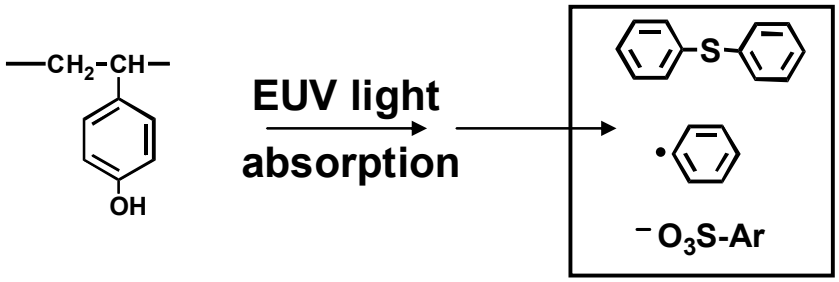
EUV acid generation mechanism



Acid generation consists of several key steps initiated by EUV light absorption

Experimental demonstration

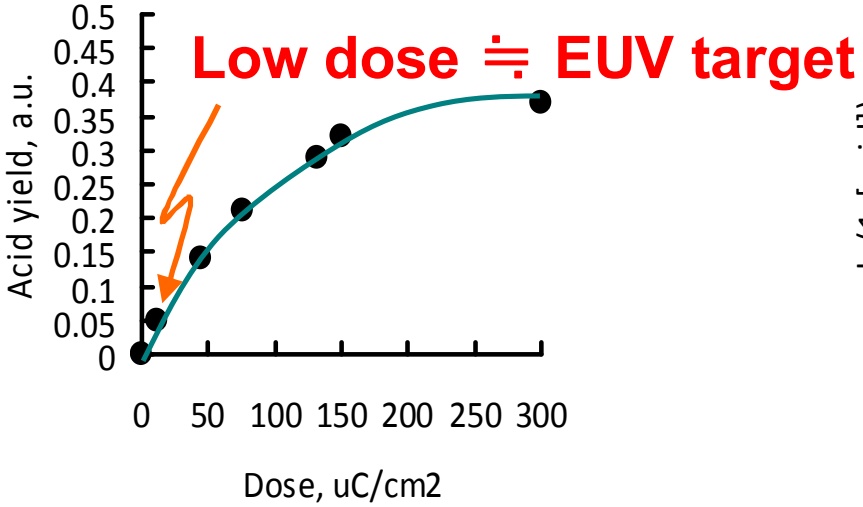
~ E-beam model experiment for acid generation ~

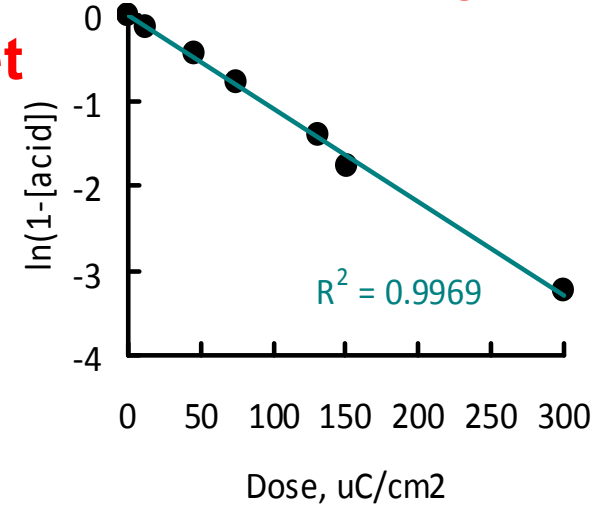


Exposure energy
⇒ EUV absorption

$[H^+] = 1 - \exp(-C \times dose)$

PAG decomposition
can be fitted by *Dill* model



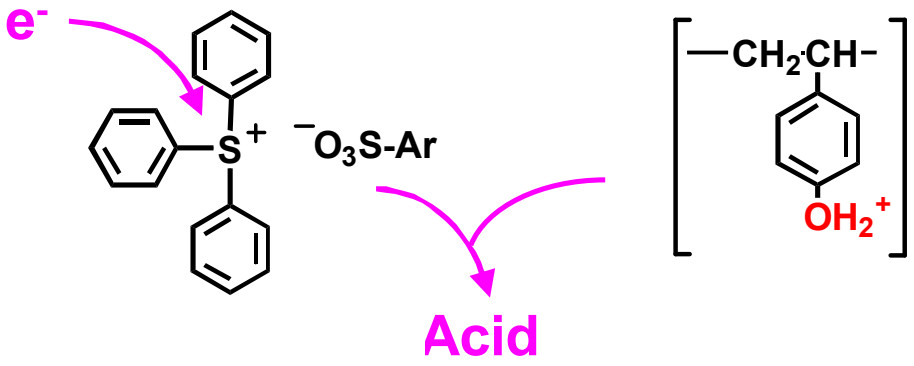


High dose results in high acid yield (normal behavior)
⇒ high absorption is necessary for high acid @low dose

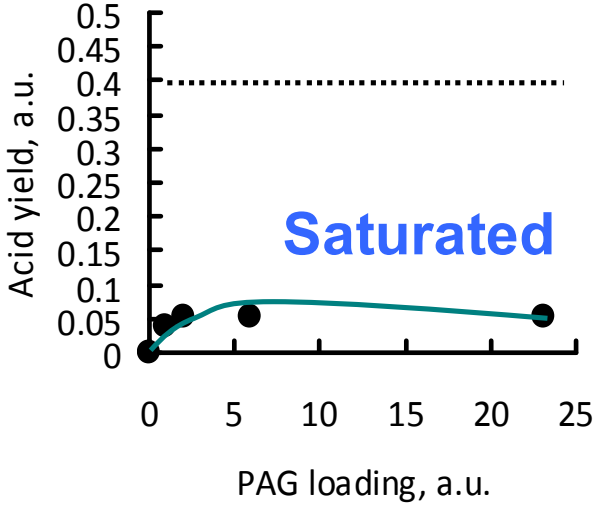
Contribution of the other processes ?

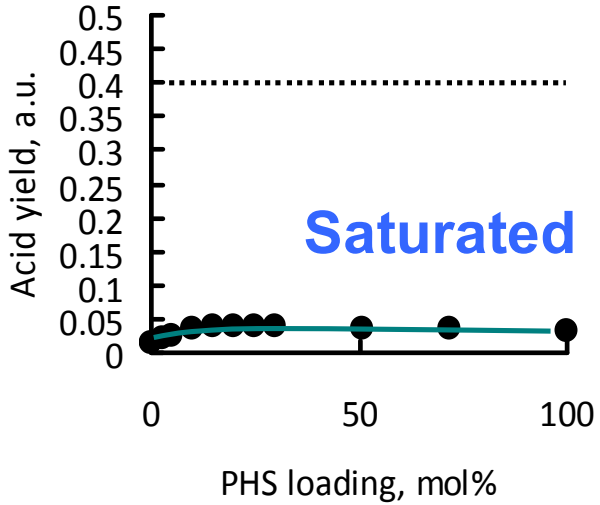
~ E-beam model experiment for acid generation ~

Electron trap
⇒ PAG loading



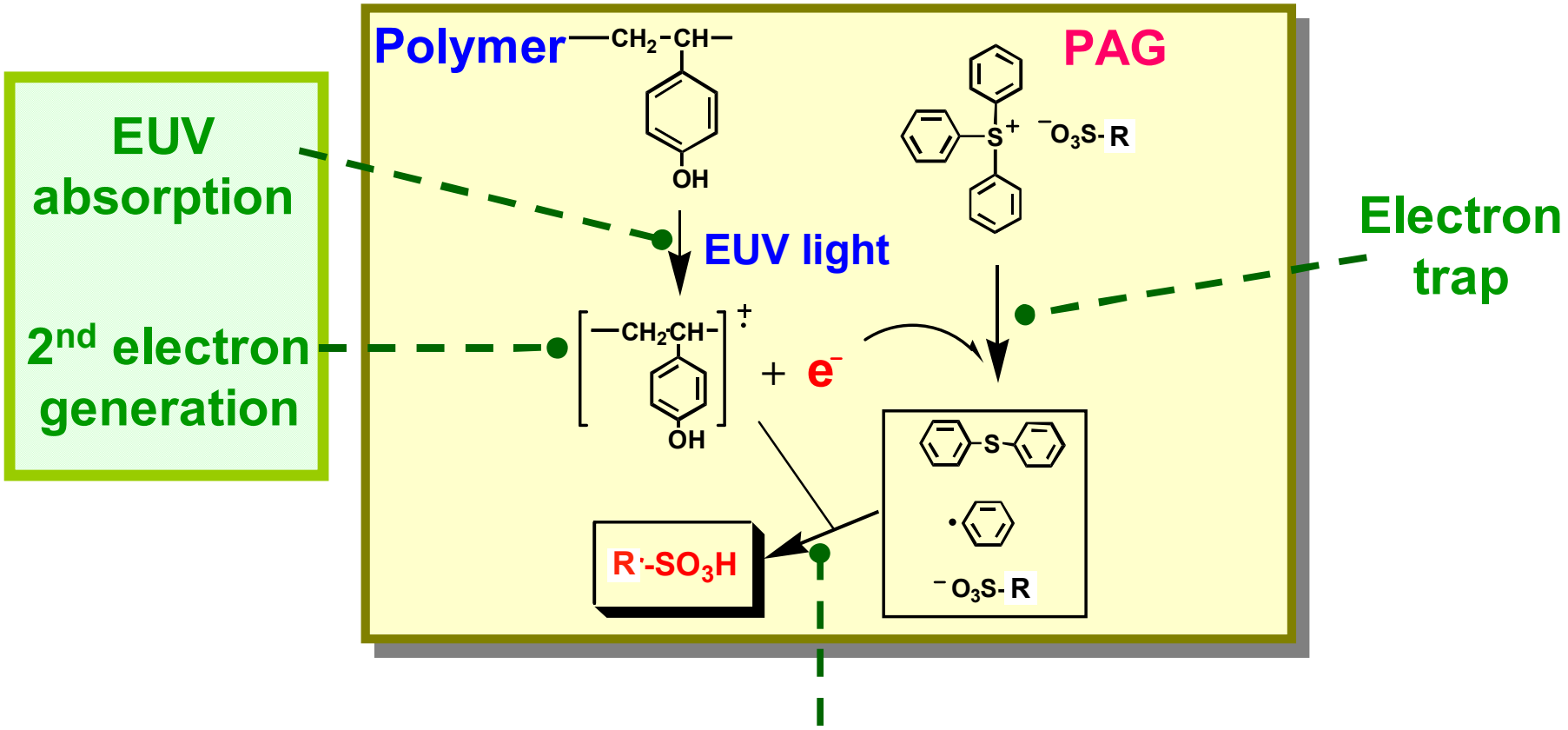
Recombination of anion and H+
⇒ H+ source
⇒ PHS loading





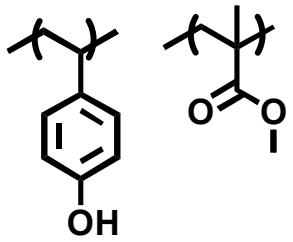
Efficiency of subsequent electron trap & acid generation processes are already maximized

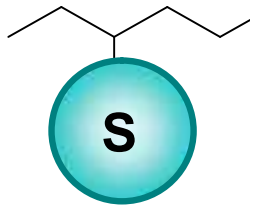
EUV acid generation mechanism



Limiting process should be
"EUV absorption" and resulting "2e- generation"

EUV sensitization by absorption increase

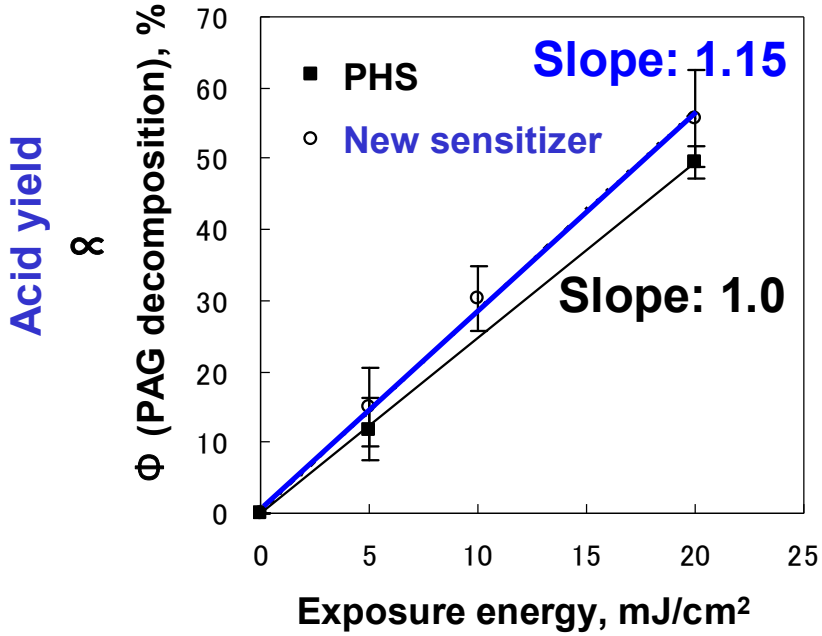




New sensitizer
w./ EUV absorbing unit

EUV absorption μ:	**4.3**	**5.7**
EUV acid yield:	**1.0**	**1.15**

Consistent with # of 2nd. electron



x 1.15 acid yield was achieved using a new sensitizer

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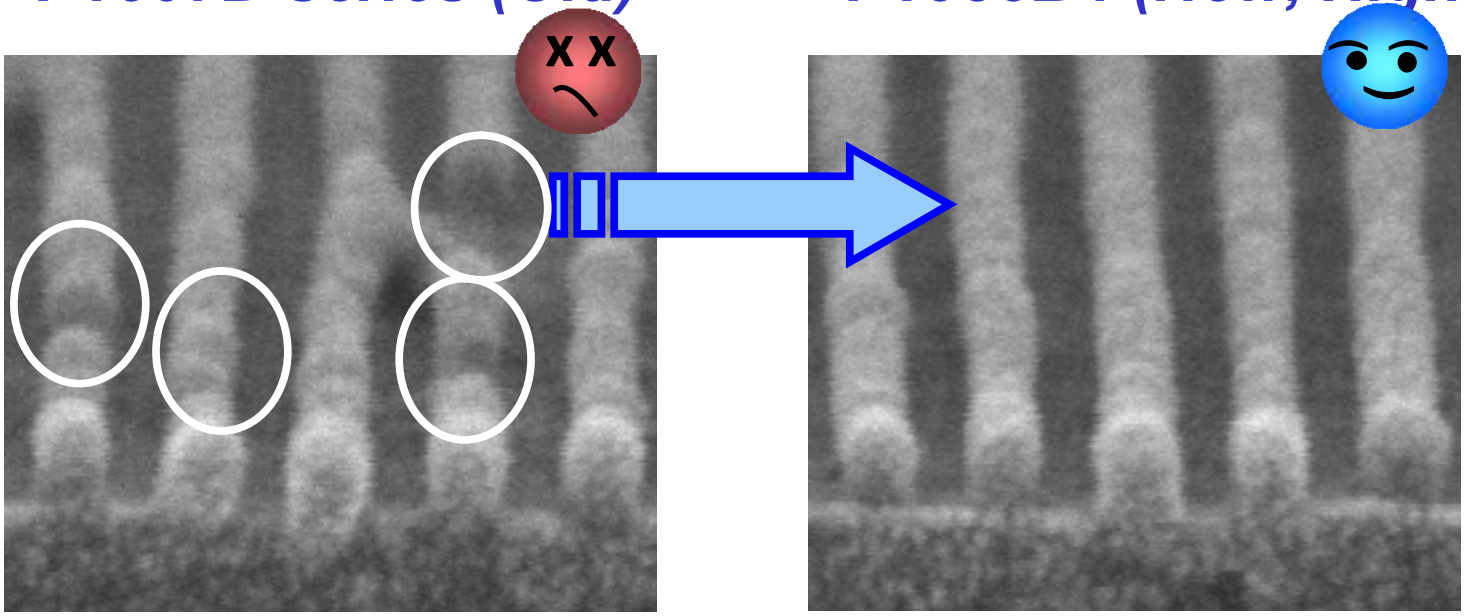
FUJIFILM EUV resist status update

-- FEVS-P1935B4 --

E-beam point beam (50keV), DIW rinse @ 16nm hp

P1507D series (Old) ***P1935B4 (New, High Tg)***



FEVS-P1935B4 well resolved 16 nm hp w./o. pinching
(Notes: E-beam exposure)

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Summary

1. **FEVS-P1507D4** resolved 15nm HP (**partially 14 nm**)
   with LWR of 3.0 nm, and sensitivity of 30.8 mJ/cm^2.

   ⇒ Z-factor : 3.7E^{-9} mJ·nm^3 (best to our knowledge)

2. **Pinching** degraded LWR of 15 nm HP,
   and this should be originated by **noise** and **contrast degradation**.

3. **Short diffusion molecular PAG** was still effective for 15 nm HP.
   Bound PAG may be not necessary even for such a narrow pitch

4. **EUV acid generation** was limited by EUV light absorption
   and secondary electron generation.

5. **EUV sensitizer w./ EUV absorbing unit**
   showed 1.15 times higher acid yield than conventional PHS polymer

6. **FEVS-P1935B4 (new resist w./ high Tg) resolved 16 nm HP (E-beam)**
   without pinching

Acknowledgement

• For the EUV exposure using MET

SEMATECH

BERKELEY LAB

Thank you for your kind attention.

FUJIFILM